C E E R E
Center for Energy Efficiency and Renewable Energy
Building Energy Efficiency Program

University of Massachusetts
Department of Mechanical and Industrial Engineering
160 Governor's Dr.
Amherst, MA 01003-9265

OUTLINE OF TECHNICAL CHANGES IN COMPUTER ALGORITHMS FOR NFRC SIMULATION PROGRAM

Submitted by: Dr. Dragan Curcija

September, 2001

Center of Glass Changes:

1) **Height dependent indoor surface heat transfer coefficient**

   Summary: Current interior convective heat transfer coefficient (often referred to as convective portion of film coefficient) is temperature dependent but not height dependent. The new correlation is also height dependent. When compared to proposed new correlation, existing correlation was analogous to 0.5 m flat plate. Considering that proposed new standard NFRC height is at least 4 ft (1.2 m), this will create noticeable differences

   Effect: Reduce U-Factor

2) **Aspect Ratio (Width/Height) dependent gap convective heat transfer**

   Summary: Current convective heat transfer correlations are independent of height and aspect ratio and are generally different than proposed new correlations. Proposed new correlations are aspect ratio (A) and height (H) dependent for cavities with A < 20.Most products will be extremely minimally impacted. However, differences will be noticed with true-divided lite products.

   Effect: Increase U-Factor

   [For 1 and 2 above, do we want to say W5 assumes a 1m high default for IGs but for the exact window, it does the height dependent calc. I think it does this, or does it assume 1m default all the time?)

3) **Different Outdoor (Exterior) Film Coefficient:**

   Summary: New proposed correlation for outdoor convective heat transfer coefficient is significantly different than existing correlation. Current correlation was developed based on outdoor measurements and it was based on free stream wind velocity. The new correlation is for laboratory conditions and is based on near surface air velocity. Therefore it is necessary to correct standard air velocity (or often called "wind speed") so that the outdoor heat transfer coefficient remains at the present level of 30 W/m^2K. The main reason for the adjustment of velocity rather than heat transfer coefficient is that laboratories standardize on the value of coefficient and not air velocity. The new proposed standard air velocity is v=5.5 m/s, for Winter conditions and 2.75 m/s for Summer conditions.

   Effect: None

4) **New Gas Thermo-physical Properties and Gas Mixture Algorithms:**

   Summary: New algorithms for the calculation of temperature dependent thermo-physical properties are very different than the existing ones, although the absolute values do not differ by much. Gas mixtures are calculated according to well documented and accurate procedure.

   Effect: Varying. Magnitude untested, but does not appear to be large.

5) **Modified Solar Heat Gain Calculations:**

   Summary: New procedure for calculating SHGC delineates fully between night time and day time performance. The SHGC is based on heat flow through fenestration calculated by subtracting the total heat flow with solar radiation from the heat flow under the exact same conditions but w/o any solar radiation. The SHGC is then ratio of this quantity to incident solar radiation. In this definition, U-factor is always fixed quantity independent of solar radiation, as opposed to the current procedure where it was fluctuating depending on the incident solar radiation.

Effect: Increased SHGC by very small amount.

Frame and Edge of Glass Changes:

6) **New Effective H and W of Frame Cavities:**

   Summary: According to the new algorithm, effective heights and widths of frame cavities are determined from their irregular shapes using well-defined scheme. As opposed to the current method, the area of the equivalent rectangle is the same as the area of irregular frame cavity, with aspect ratio of sides being equal to largest horizontal and vertical dimensions. Correlations are largely the same as before.

   Effect: Lower U-Factor

7) **Updates of Temperatures and Heat Flow Directions in Frame Cavities:**

   Summary: The current procedure has fixed temperature difference and heat flow direction (horizontal) independent of the actual situation. The new procedure has again well-defined scheme for the determination of temperatures and heat flow directions depending on the position the cross section has in a fenestration system (i.e., sill, head, jamb, or meeting rail), as well as the actual heat transfer through a cross section.

   Effect: Varying, but likely to slightly lower U-factors.

8) **New Correlations for Jamb Frame Cavities:**

   Summary: Jamb cross-sections are usually tall vertical cavities and they were currently incorrectly modeled the same way as sill and head cross-sections. In the new procedure, jamb cross sections, as well as vertical mullions, are treated as tall enclosures, where heat flow always occurs in horizontal direction, whether it is in the plane of glazing or perpendicular to it.

   Effect: Higher U-factors.

9) **New Radiation Correlation for Frame Cavities:**

   Summary: The new correlation more correctly accounts for the shape of frame cavity

   Effect: Slightly higher U-factors

10) **New Definition of "Open" Frame Cavities:**

   Summary: Frame cavities that are partially open to the environment were treated according to the "5 times" rule. This rule was never documented and it is unknown where it came from. According to the new procedure, there are three types of partially open cavities, 1) essentially closed cavities, having the same effective conductivity as completely enclosed cavities (connecting slot less than 2 mm), 2) slightly ventilated frame cavities, having effective conductivity twice the value of completely enclosed cavity (connecting slot between 2 and 10 mm), and 3) well ventilated frame cavities, which are treated as fully open boundaries (connecting slot greater than 10 mm). This rule is the same on indoor and outdoor side, as opposed to the current rule, which applied to outdoor side only.

Effect: Higher U-factor

11) Modified Correlation for Frame Solar Heat Gain:

Summary: The new correlation for solar heat gain calculations of frame cross sections is similar to the existing correlation, with the addition of developed to projecting frame area ratio and outdoor heat transfer coefficient. The new correlation is based on ASHRAE published work.

Effect: Slightly LOWER??? SHGC; noticeable for aluminum frames but negligible for others

12) Meshing/Gridding of Model Geometry Based On Estimates of Errors:

Summary: In the current methodology it was possible to perform calculation with arbitrary looking mesh, without checking on the accuracy of answers. The new procedure specifies steps how to check accuracy of the solution.

Effect: Lower U-Factor

13) Accuracy of Geometry Representation:

Summary: In the new procedure, it is precisely prescribed how to check the validity of geometric representation. For example, programs that can represent only approximation of the real geometry (e.g., approximating sloped lines with horizontal and vertical lines, or representing curved lines with several straight lines) will have to follow set of rules described in ISO 15099. Currently, this was left to the discretion of the simulator and several different (often conflicting) versions of the same model file were possible.

Effect: Varying. Depending on the particular case, but it is expected to slightly increase U-factor.

14) Adjustment of the Conductivity Or Cross-Sectional Thickness of the Thermal Bridging Element When Approximating Real Geometry:

Summary: Currently, thermal bridging elements in the model (e.g., spacer detail) are sometimes approximated with the net result of increased thermal path (i.e, representation of sloped spacer wall with the series of horizontal and vertical pieces). The new procedure will require appropriate increase in thermal conductivity to account for increased thermal path or increased cross section thickness, whichever is more appropriate and easier.

Effect: Increased U-factor for Models Done with Approximating Geometries

15) Introduction of Environmental Temperatures in U-Factor Calculations:

Summary: U-Factors are defined in the new procedure wrt the difference between indoor and outdoor environmental temperatures. This is consistent with testing procedure. The environmental temperature will be different from air temperature when the mean radiant temperature is different then air temperature. This is not the case in NFRC simulation procedure, where air and radiant temperatures are the same.

Effect: None

16) Change in Convective Heat Transfer Coefficient For Frame Sections:

Summary: Currently, convective heat transfer coefficients are applied to frame sections based on their construction (i.e., wood/PVC, Aluminum, or thermally broken Aluminum) In addition, the radiative portion of the heat transfer coefficient was calculated for each type of frame section, resulting in three separate film coefficients for three different frame constructions, regardless of the glazing that goes with that frame. In the new procedure, the convective heat transfer coefficient will be only dependent on the glazing system, as the dominant and driving force in convection heat transfer. The radiation heat transfer will be calculated for each segment of the numerical grid and will depend on actual temperature of that segment (updated computationally) and emissivity of that segment.

Effect: Unknown, but expected to be small.

Outline of Technical Changes in Computer Algorithms Independent of New ISO Standard:

1) **New Standard NFRC Sizes:**

   Summary: New NFRC sizes are better harmonized with CEN sizes and are generally larger than current sizes.

   Effect: Lower U-factor

2) **Change in the Length of Glazing That is Modeled With Frame Section:**

   Summary: While the edge of glass length remains 2.5 in (63.5 mm), the length of the glazing that is simulated along with the frame section increases to 6 in (150 mm). The section from the end of edge of glass region to the end of glazing section will have U-factor tag "None" and will not be considered in heat transfer calculations. This change was done because of the need to have consistent glazing length with or without detailed radiation model.

   Effect: Negligible for standard radiation model. Lower U-factors for detailed radiation model (depending on how projecting the product is).

3) **Change In A Way Dividers Are Modeled:**

   Summary: Dividers were modeled so far as quasi glazing layers and imported into 2-D program from center of glass calculation tools, after which they are adjusted to complete connecting sections of the divider cross section. The new procedure treats dividers as frame sections, and it only imports true glazing layers, where the dividers are completely drawn in 2-D computer tools. One of consequences of this approach is also the addition of different gas and gas mixtures calculations into 2-D tools. The space between divider and glass is treated as frame cavity.

   Effect: Lower U-factor.

4) **Change in Mitering of Divider Edge Corners:**

   Summary: Divider edge regions were mitered in the corner in the current procedure. In the new procedure this will change into butt joint.

   Effect: Unknown, but likely very small.